INTAKE PORT FLOW STUDY ON VARIOUS CYLINDER HEAD USING FLOWBENCH

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A report is submitted in partial fulfillment
of the requirements for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
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SUPERVISOR DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Signature :

Name of Supervisor: Mr. Fairusham
Position:
Date:

Signature:

Name of Panel:
Position:
Date:

STUDENT DECLARATION

I declare that this thesis entitled "Intake Port Flow Study on Various Cylinder Head Using Flowbench" is the result of my own research except as cited in the reference. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Mohd Taufik Bin Abd Kadir

Date : …………………………….

Dedicated to my beloved Parents and Family,

Especially to my late Mother,

Thank you for all the supports and encouragement during

This thesis is being made..

ACKNOWLEDGEMENTS

In the name of ALLAH SWT, the most Gracious, who has given me the strength and ability to complete this study. All perfect praises belong to ALLAH SWT, lord of the universe. May His blessing upon the prophet Muhammad SAW and member of his family and companions.

I feel grateful to Allah S.W.T because this project has successfully completed. In completion this final year project, I was in contact with many people that contributed toward my understanding and problem solving. In particular, I wish to express my sincere appreciation to my project supervisor, Mr. Ismail Bin Ali for his guidance, advice and encouragement. I am deeply thankful to everyone who assisted me on this project especially to all staff FKM laboratory for their assistance and support.

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Not forgetting my family members in giving me lots of supports in the aspects of moral, social and financial during my degree. This project definitely not exists without full encouragement from them.

ABSTRACT

Modification on intake port flow by enlarging the intake port area can increase engine performance. Higher air flow rate entered the intake port resulting higher air-fuel rate burn thus increased the performance of the engine. This report are consist of experiment of intake port flow between two cylinder head, Toyota 4AGE 1.6L and Proton 4G92 1.6L.Modification works will be porting, polishing, removing valve guide and additional mounted velocity stack. Effects of modification through both cylinder head are experimentally tested by opening valve lift with significant value by calculations using Superflow® SF-1020 Flowbench machine. The experiment will consist of intake valve flow rate, the effect of velocity stack and swirl motion in bore. It is proved by experiment result that porting, polishing and removal valve guide in the intake port area works significantly increased the flow into the engine and consequently changes the swirl speed to a higher values for both cylinder head and tremendous increased when the velocity stack is added along with the modification works.

ABSTRAK

Modifikasi pada bahagian kemasukan aliran jisim udara dengan pembesaran kawasan kemasukan aliran udara boleh meningkatkan prestasi enjin. Peningkatan kenaikan kadar kemasukan jisim udara meningkatkan kadar pembakaran jisim udara dan bahan bakar yang mengakibatkan peningkatan mendadak prestasi enjin. Repot experimen ini mengandungi kajian tentang kadar jisim udara masuk antara dua jenis kepala silinder iaitu Proton 4G92 1.6L dan Toyota 4AGE 1.6L.Kerja-kerja modifikasi adalah seperti ”porting”, ”polishing”, penghapusan panduan injap udara masuk dan penambahan cerobong kelajuan.Kesan daripada modifikasi kedua-dua kepala silinder akan diuji keberkesanannya melalui experimen dengan pembukaan injap udara masuk melalui pengiraan kadar pembukaan injap udara masuk dengan menggunakan mesin Superflow® SF-1020 Flowbench.Experimen pada ruang aliran jisim udara masuk ini merangkumi kadar jisim udara masuk, kesan penggunaan cerobong kelajuan dan kesan pergerakan pusaran pada bor.Telah terbukti dalam experimen bahawa kesan daripada kerja-kerja ”porting”, ”polishing” dan penghapusan panduan injap udara masuk di kawasan kemasukan aliran udara dapat meningkatkan kadar jisim udara yang masuk ke dalam kepala silinder mengakibatkan perubahan kadar kelajuan pusaran di dalam bor kepada kedua-dua kepala silinder and peningkatan yang menakjubkan jika modifikasi disertakan juga dengan cerobong kelajuan udara.

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LIST OF SYMBOLS

A_m	-	Minimum area
L_v	-	Valve lift
β	-	Valve seat angle
D_v	-	Valve head diameter
w	-	Seat width
D_m	-	Mean seat diameter
D_p	-	Port diamater
D_s	-	Valve stem diameter
RPM	-	Revolution per minute
cfm	-	Cubic feet per minute
CD	-	Coefficient of discharge
lps	-	Liter per second
in	-	inch
mm	-	millimeter
cm	-	centimeter
cmh	-	cubic meter per hour
MEP	-	Mean effective pressure
HP	-	Horsepower

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CHAPTER 1

INTRODUCTION

1.0 Project Background

The myth of modifying cylinder head to optimize the horsepower and air-flow of the engine are not impossible this day. Modifying the intake port have many types and rules. It is such as valve guide removed, porting, polishing and mounting velocity stack. All modifiers, modified cylinder head to have an increasing increment of horsepower and air-flow and thus the engine efficiency will be increase too.

The flow of the intake port is measured by coefficient of discharge(CD) and the increasing of horsepower produced. A wide variety of inlet port geometry patterns will affected the amount of air entered the port.

This investigation studied were strictly to know the effect of cylinder head modification to improve horsepower .The effectiveness cylinder head geometry of the intake port for both cylinder head testing will be compared by using lift over diameter ratio(L/D ratio).Performance parameters will be analyze through data collecting from Flowbench and Swirl meter machine.

1.1 Problem statement

Considering the flow through intake port as a whole, the greatest loss must be downstream of the valve due to the lack of pressure recovery. Because of that, this studies to investigate the flow characteristics of the both two cylinder head. We need to know how much performance difference the Toyota cylinder head compared to the Proton cylinder head. This will be the basis for conclusion regarding this works.

This study also concern about the improvement of the power itself compare to the old cylinder head of both engine and how much the increment of power that will relies when this analysis on improvement of both cylinder head. Means that, the power output as a result the port airflow effect from the modification port that has been done is what the most importance to be known.

The flow itself is calculated by using the term of horsepower. High airflow enters the intake port area also increases the horsepower. The term of comparison is what the importance parameters that must be taken care of. It will show the improvement of flow for both cylinder head. Because of that the standard analysis is used to compare both cylinder head so that this study analysis can be guidance for any improvement or analysis to both cylinder head.

1.2 Objectives of the project

1) Analysis intake port for types of flow at two cylinder head engine that is Toyota 4AGE 1.6L and Proton 4G92 1.6L.

2) To determine how much power improvement at the modified intake port compared to the original intake port.

1.3 Scopes of the project

1) Analysis and comparison for measure air flow at both cylinder head at the intake port for Toyota 4AGE 1.6L and Proton 4G92 1.6L.

2) Using Superflow SF-1020 Flowbench machine to measure the flow rate through 4 different intake port conditions.

3) Modify intake port using 3 method that is porting, polish and additional velocity stack.

4) Identify the increasing performance after the modification works done.

5) The flow and swirl testing results will not be compared to specification of both engines from the manufacturer.

THESIS FLOW CHART

Intake port flow study on various cylinder head using Flowbench

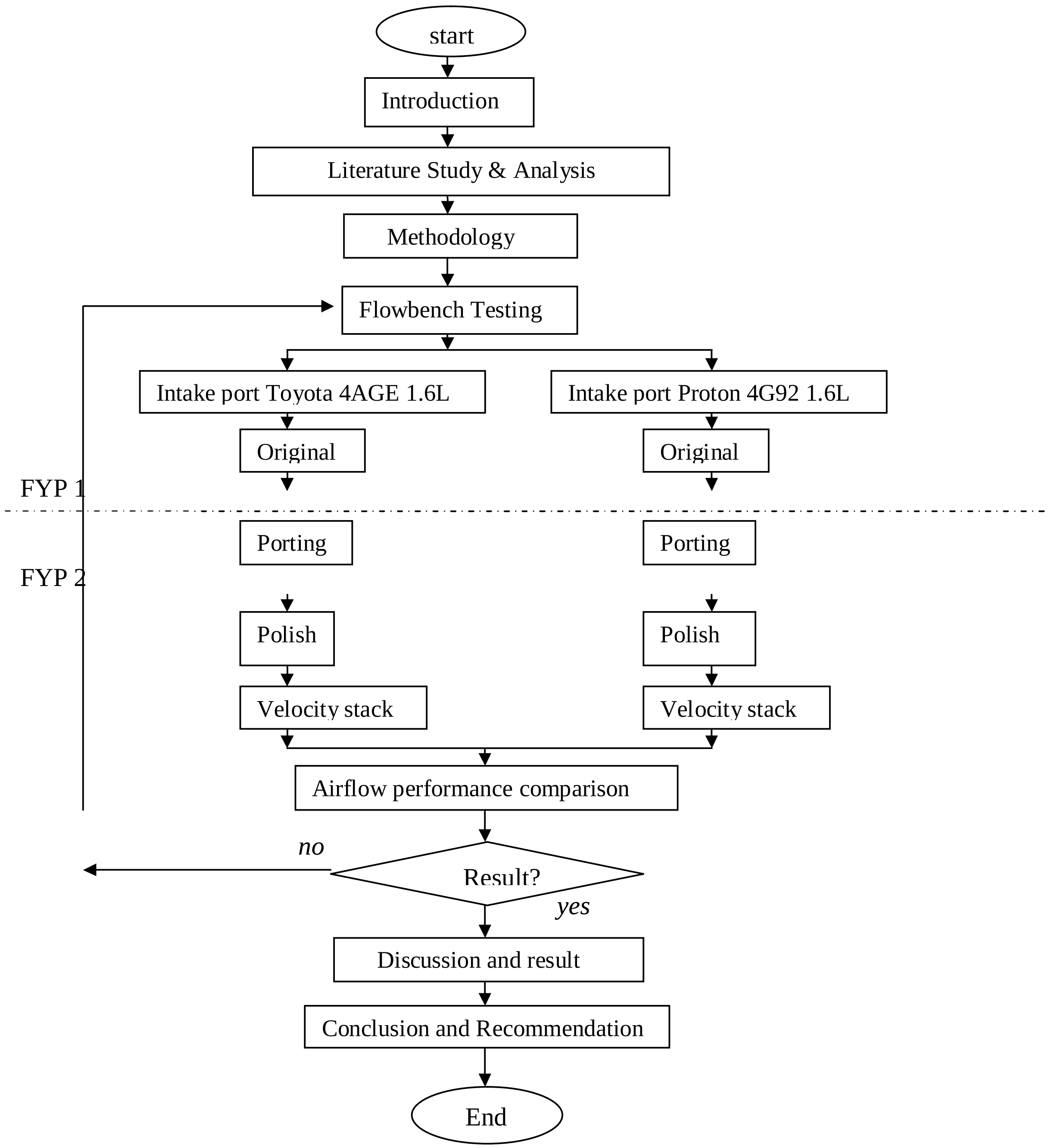


Figure 1: Flow chart of the project

CHAPTER 2

LITERATURE STUDY

2.1 Introduction

Automotive industries nowadays have enlarged in impressive ways. The internal combustion engine first developed at year 1876 until now, the engines have continued to develop as the knowledge of engine processes has increased, where new technologies have been invented and available as the demand for new cars and new engine arose.

Modification to the engine without additional system attach to the engine operation were the best solution to have an optimum engine operation in term of torque and horsepower. To optimize the power and intake port flow produce by the engine modification were through a very limited value. The value is limited due to the restricted area of the engine production by the manufacturer.

Analysis on the cylinder head is consist of Toyota 4AGE 1.6L 16-valve DOHC and Proton 4G92 1.6L 16-vave SOHC engine .Flow that through the intake port will show the differences between both of the cylinder head. High flow of fuel that can enter the cylinder head will determined the performance of the engine. The performance can be defined by the terms flow and horsepower.

Both cylinder head will be analyzed by using the flow machine SF-1020 Flowbench. The cylinder head is bolted to the cylinder block and covers the top of the cylinder bores. Type of cylinder head will determined for better breathing, improved combustion and more efficient, lighter valve rains-reduced inertia allowing higher engine operating speed. It also shows how much the swirl in the combustion chamber. The term swirl is the name of organized movement of the air and fuel mixture in the cylinder. Then generate more power because of higher mixture than make the fuel burn perfectly.

2.2 Engine specification

Table 1: Proton engine 4G92 1.6L

Description	Specification
Type	In line OHV, SOHC
Bore and stroke	81 mm x 77.5 mm
Valve	16, 4 per each cylinder
Power	111 bhp (83 kW/113 PS) @ 6,000 rpm
Torque	138 N·m (102 ft·lbf) @ 5,000 rpm
Redline	7000 rpm

Table 2: Toyota engine 4AGE 1.6L

Description	Specification
Type	DOHC Inline-4 (Straight-4)
Bore and stroke	81 mm × 77 mm
Valve	16, 4 per each cylinder
Power	115–140 hp (96–103 kW) @ 6600 rpm
Torque	109 ft·lbf (148 N·m) @ 5800 rpm
Redline	7600 rpm

2.2.1 Intake port design

Intake port design of an engine is specifically follow the type of combustion chamber type of that type of engine.

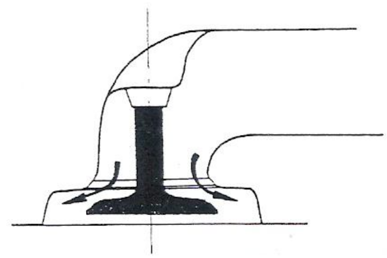


Figure 2: Proton intake port design

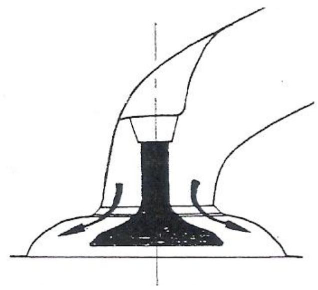


Figure 3: Toyota intake port design

2.2.2 Poppet valve design

There are several types of valves that are used: a poppet, rotary, disc and a sleeve. The most common valve is the poppet valve. The poppet valve is inexpensive and has good sealing properties, making it such a popular choice.

2.3 Intake port flow

In the cylinder head, the importance parts to increased the performance is the intake and exhaust port. The importance of both port effect the performance of the engine and also the engine efficiency. The instantaneous valve flow area depends on valve lift and the geometric details of the valve head, seat and stem. There are 3 separates stages to the flow area developments valve lift increases[1].

The stages are :

1. First stage

For low valve lifts, the minimum flow area corresponds to a frustrum of a right circular cone where the conical face between the valve and the seat, which is perpendicular to the seat, defines the flow area.

The minimum area is;

$$A_m = \pi L_v \cos\beta\,(D_v - 2w + (L_v/2)\sin 2\beta) \qquad (2.1)$$

Where: β = Valve seat angle [º]

L_v = Valve lift [mm]

D_v = Valve head diameter (the outer diameter of the Seat) [mm}

w = Seat width (difference between the inner and outer seat radii) [mm]

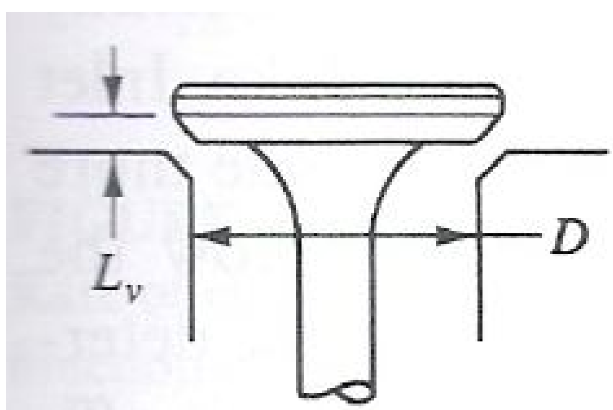


Figure 4: First Stage of valve lift operation

2. Second stage

For the second stage, the minimum area still the slant surface of a frustrum of a right circular cone, but his surface is no longer perpendicular to the valve seat. The base angle of the cone increases from $(90-\beta)^o$ toward that of a cylinder, 90^o.

The minimum area is;

$$A_m = \pi D_m [(Lv - w \tan \beta)^2 + w^2]^{½} \quad (2.2)$$

Where: D_m = Mean seat diameter (D_v – w) [mm]

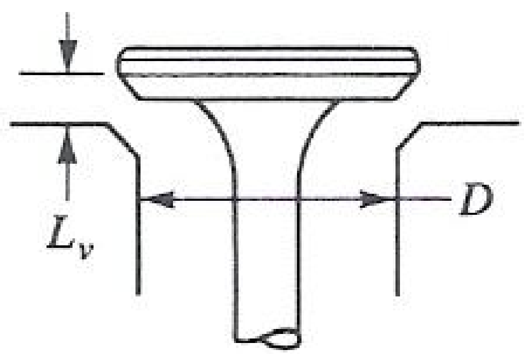


Figure 5: Second stage of valve lift operation

3. Final stage

Finally, when the valve lift is sufficiently large, the minimum flow area is no longer between the valve head and seat; it is the port flow area minus the sectional area of the valve stem.

The minimum area is;

$$A_m = \frac{\pi}{4} (D^2_p - D^2_s) \tag{2.3}$$

Where: D_p = Port diameter

D_s = Valve stem diameter

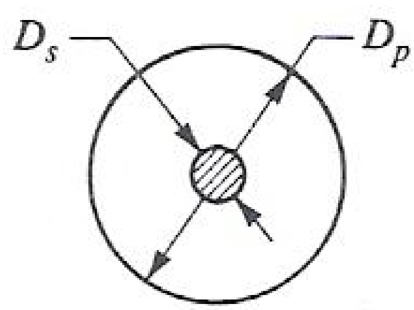


Figure 6: Final stage of valve lift operation

In the intake port, the air-flow motions are in turbulent motions. In turbulent flow, the rates of transfer and mixing are several times greater than the rates due to molecular diffusion. This turbulent diffusion results from the local fluctuations in the flow field. It leads to increase rates of momentum and heat and mass transfer and is essentials to the satisfactory operation of spark ignition and diesel engines.

Turbulence is rotational and is characterized by high fluctuating vorticity: these vorticity fluctuations can only persist if the velocity fluctuations are three dimensional. The characteristic of a turbulent flow depends on its environment. In the engine cylinder the flow involves a complicated combination of a turbulent shear layers, recirculating regions and boundary layers. But, the most important characteristics of a turbulent flow is randomness irregularity.

2.4 Flow losses in an intake port

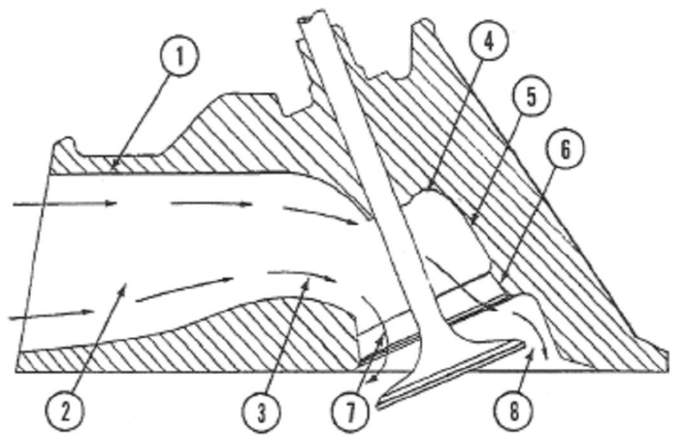


Figure 7: Flow losses in the intake port[1]

In order to increase the intake flow performance, the flow losses in the intake port area must be analyzed. Those losses have restrict the mass air-flow rate entered the intake port. Thus, the air-flow rate enter decreased. Before the modification works is done, it needs to overcome the losses. Generally, the intake port is design to limited with the engine bore specifications. To eliminates all the losses is impossible and the easiest ways is to smoothen the air-flow entered and increased the intake port scale by modification.

Referring to figure 3, the flow losses in the intake port area were describe clearly through the losses from each part in the port. To increase the performance, hose losses should be eliminate.

Table 3: Percentage of flow losses in intake port.

No.	Source of flow loss	% of loss
1.	Wall Friction	4
2.	Contraction at push-rod	2
3.	Bend at valve guide	11
4.	Expansion behind valve guide	4
5.	Expansion 25 degrees	12
6.	Expansion 30 degrees	19
7.	Bend to exit valve	17
8.	Expansion exiting valve	31
	Total	100

2.5 Technique of modification

Getting air into an engine is the key to making power and there are many ways to increase the air flow into the engine. There are such forced induction, nitrous system, better port and valve shapes to improve flow. But for this study the technique that has been selected were the better port size. The claims that this where the harnessing the inertia of the airs velocity to better fill the cylinders is have to proved.

The modification technique used is the removal valve guide, porting, porting and polishing the intake port. The possibilities of increasing flow after the modifications have done are importance. The port modification should be to get as much flow and velocity as possible in those intake port designs as a little restriction.

2.6 Swirl

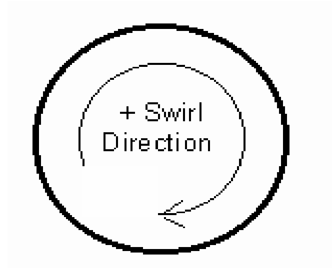


Figure 8: Swirl direction view from top

The values of swirl are always in debate with race engine or performance builders. A few years back, the swirl existence in the combustion chamber is the most of engine builders feared. It causes the fuel out of the intake charge in the cylinder due to the motion direction. However, this proved only if the effect of lower intake charge temperatures and fuel droplets is too big. Cooler intake charges from the thermal-barrier manifold coatings meant the fuel leaving the carb booster needed to be more atomized. If the requirement is fulfill, the swirl motion is important.

Swirl motion is an organized rotation result from the air-flow motion in the intake charge. The importance of existence the swirl motion is to helps mixing the fuel and air rapidly. The swirl motion generates according to the perimeter of bore. The rotation will continue in the combustion chamber until the combustion or ignition process started. In this case, the swirl helps rapid air-fuel mixing and resulting speed up of combustion process. The momentum of the swirl motion helps increased the mixing process.

2.6.1 Swirl meter

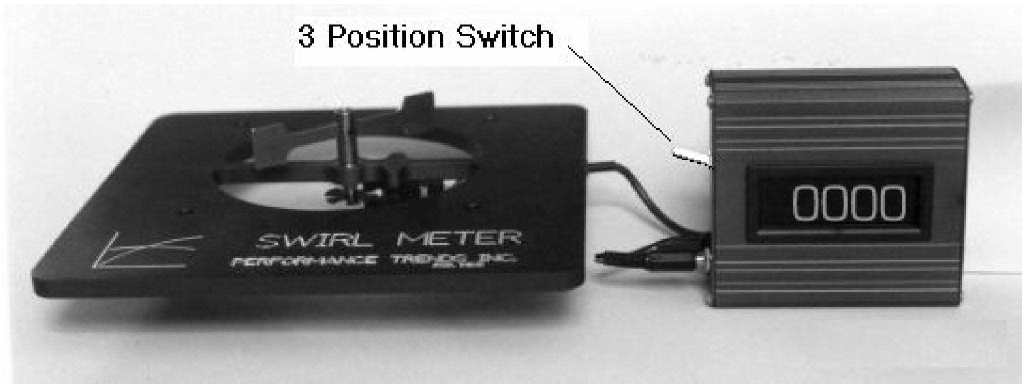


Figure 9: Swirl meter used for swirl experiment

The swirl meter is designed to measure the circular motion of combustion air on a steady state flow bench. Engine research has shown that mixture motion improves combustion efficiency burn rate. Both of these trends improve engine power output and efficiency. Improved efficiency means that power can improve even if the engine's air flow does not improve. This is especially important is restricted classes of racing, where restrictor plates limit engine air flow.

Tests have shown the swirl meter does not restrict flow significantly (less than 2 *cubic feet per minute* out of 400).Therefore, the swirl RPM data can be taken although flow testing were done exactly at the same time .Swirl readings will change with test pressure and CFM flow and other factors such as distance meter from the cylinder head, clearance between paddle wheel and bore adapter, weather, bearing friction and temperature, etc.

Referring to figure 2, the swirl meter consists of 3 position switch. Top position is 0.5 second update. Middle position is 5 second average update. Hold in down position to display minimum, average and maximum swirl RPM for last 5 second period average. The Swirl meter is mounted between the bore adapter and the Flowbench and records the gross axial, circular motion of intake. The standard 3.75" paddle wheel is designed for bores in the 4 to 4.5 inch range.

Other features of Performance Trends' Swirl Meter include low flow restriction design as the same time the measurement of intake flow can be taken. It also shows the direction of swirl, either clockwise or counterclockwise .Clockwise directions of flow indicated by positive value while counterclockwise of flow is negative value.

2.7 Coefficient of discharge (CD)

The coefficient of discharge (CD) is defined as the ratio of actual discharge to ideal discharge. In the engine environment, ideal discharge considers an ideal gas and the process to be free from friction, surface tension, etc. Coefficients of discharge are widely used to monitor the flow efficiency through various engine components and are quite useful in improving the performance of these components.

The engine efficiency are indicated thermal efficiency, brake thermal efficiency, mechanical efficiency, volumetric efficiency and relative efficiency. In this study analysis, the CD value will indicates the flow efficiency in the intake port area.

Discharge coefficient of typical inlet poppet valve in normal operating engine are effected by the intake valve lift opened. The discharge coefficient based on valve curtain area is a discontinuous function of the valve lift/diameter ratio. There are 3 segments corresponds to different flow regimes. The segments are;

1. Very low lifts

   The flow remains attached to the valve head and seat, giving high values for the discharge coefficient.

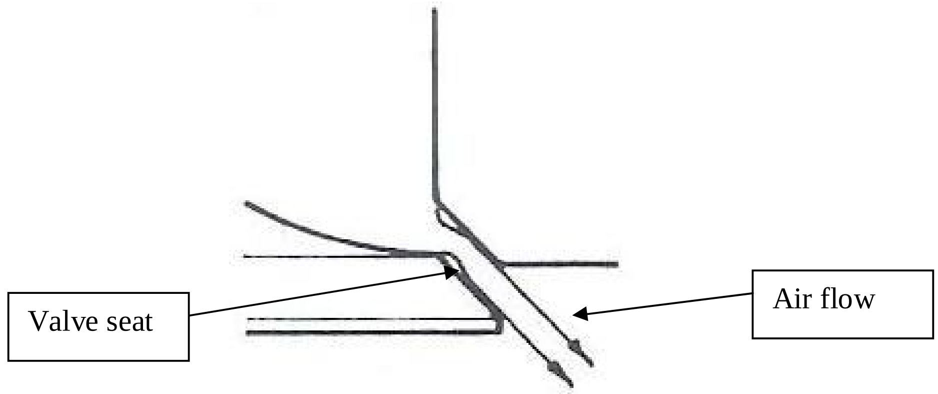


Figure 10: Flow region in low intake valve lift open

2. Intermediate Lift

The flow separates from the valve head at the inner edge of the valve seat. An abrupt decrease in discharge coefficient occurs a this point. The discharge coefficient then increases with increasing lift since the size of the separated region remains approximately constants while the minimum flow area is increasing.

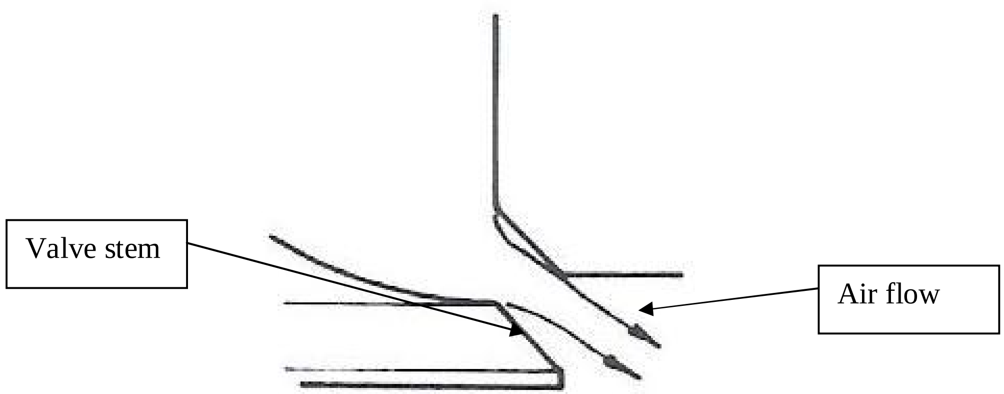


Figure 11: Flow region in intermediate valve lift open

3. High valve lifts

The flow separates from the inner edge of the valve seat as well.

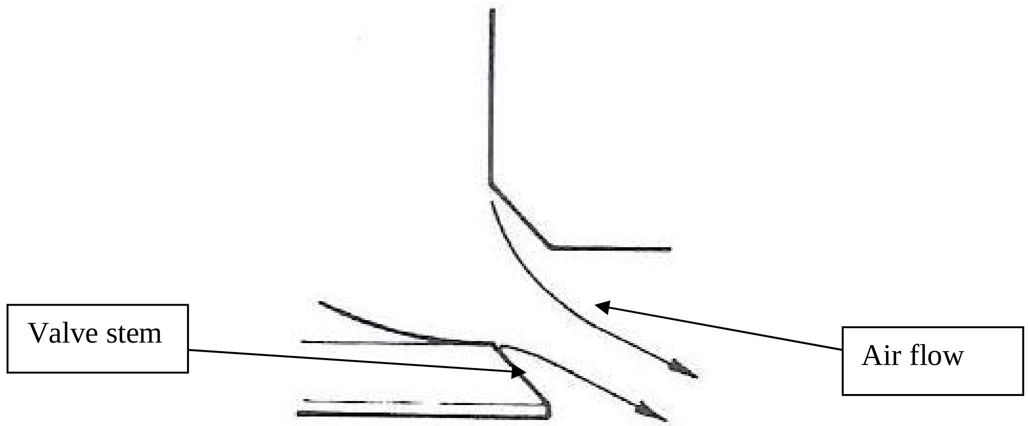


Figure 12: Flow region in high intake valve open

2.8 Flowbench system

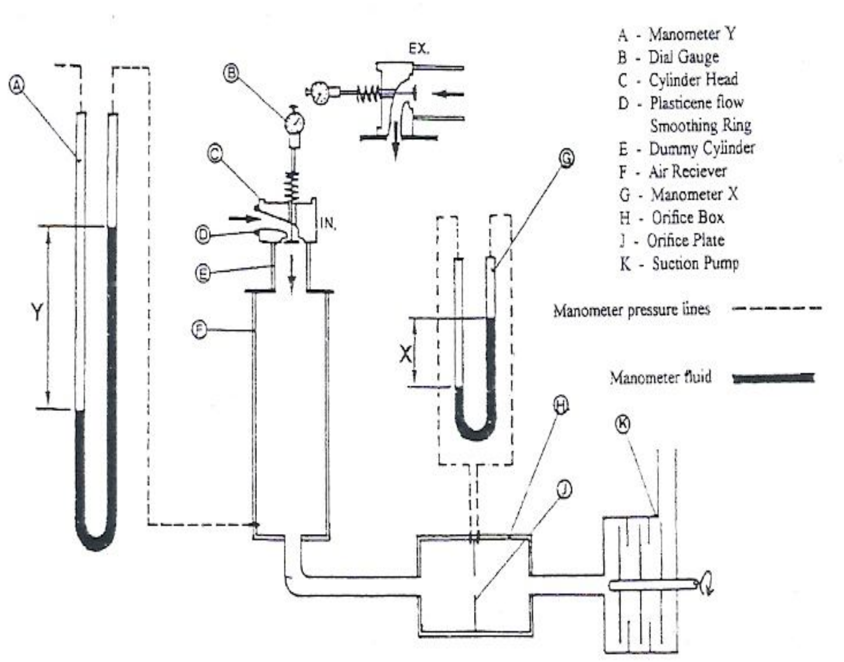


Figure 13: Schematic of Flowbench layout

The SuperFlow SF-1020 Flowbench is designed to measure air-flow resistance of engine cylinder heads, intake manifolds, velocity stacks and restrictor plates. For four-cycle engine testing, air is drawn through the cylinder head into the machine, through the air pump and exits through the vents at each side of the SF-1020 Flowbench. For two-cycle engine and exhaust valve testing, the path of air-flow is reversed by entering an Exhaust flow range.

The test pressure meter (pressure transducer) measures the pressure or vacuum at the base of the test cylinder. The flow meter measures the pressure difference across an adjustable flow orifice in the SF-1020 Flowbench. The flow meter reads 5 to 100% of any flow range selected in either intake or exhaust flow direction. The full scale flow measurement range can be varied from 25 to 1000 *cubic feet per minute*, (12 to 470 *liter per second*). The Flowbench is fast, accurate, repeatable result at any test pressure between 5”(13 cm) and 70”(178 cm) of water. Testing typically performed at 50-65” of water test pressure.

Unique variable flow orifice adjust flow range between 25 *cubic feet per meter* and 1000 *cubic feet per meter* based on FlowCom input, to fit the valve size or the valve lift. Run test in a single setting to obtain extended accuracy at low lifts, with readings all within 0.25%.The variable flow range increases resolution of flow measurements versus single-range system; 0.5% changes are easily detectable.

CHAPTER 3

METHODOLOGY

3.1 Porting

Porting is an art of modification by enlarging the port to its maximum possible size (in keeping with the highest level of aerodynamic efficiency) but those engine are highly developed very high speed units where the actual size of the ports has become the restriction. Methods for porting are usually with CNC-machine to provide the basic shape of the port and hand finishing because some area of the port is not accessible for the CNC machine. This porting process to the cylinder heads and intake ensures that the flow mixture enters the cylinder head chamber with the maximum amount of velocity.

The higher flow restriction in any engines is within the cylinder head. Porting is needed for reducing the flow restriction at the particular area to increase performance of the engine compare with the same engine with same displacement. Higher the flow entered will causing increasing velocity of the air-flow and at the same time the performance in case of horsepower will also affected.

Both intake ports are modified strictly the same as how much the porting works done is the parameter that have been fixed. Referring to figure

Figure 14: Proton intake port after porting works

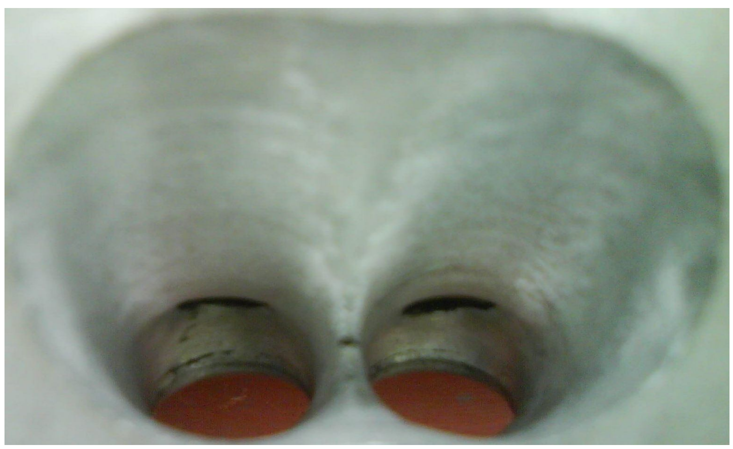


Figure 15: Toyota intake port after porting works

3.1.1 Porting tools

Air grinder were used to perform the modification works and a series of Carbide bits with different lengths, shapes, sizes, and tooth counts to perform the porting process. Referring to figure 1, the air grinder fit with the cutting tools for the modification works.

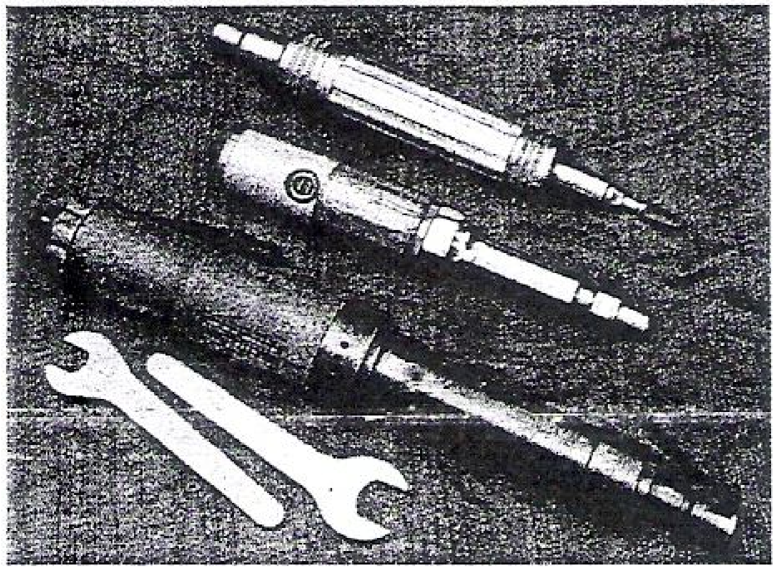
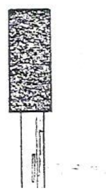
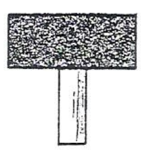
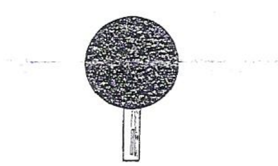


Figure 16: Air grinder for porting modification

The air grinder is used with four type of cutting tools that is cylinder type, ball type, oval type and flame type. By referring to table 4,the required tools used for the works is dependent on the surface of intake port.

Table 4: Various stones type and the function

Shape	Use	Sizes
W179 : Cylindrical 	Reshape as necessary for corners and flats of square or rectangular ports & sides of guide bosses	3/8 in diameter x 1 ¼ in long
W188 : Cylindrical 	Reshape as necessary for corners and flats of square or rectangular ports & sides of guide bosses	½ in diameter x 1 ½ in long
W227 : Cylindrical 	Roof of combustion chamber and combustion chamber wall	1 ¼ in diameter x ½ in long
A25 : Ball 	For radiused ports and for reshaping ports and valve throat to oval.	1 in diameter x 1 in long

3.2 Polishing

Polishing is another type of modifying the cylinder head. Polishing eventually did not give an extra breathe for horsepower. As this analysis is conducted to see the behavior between the rough surface and the smooth surface after polishing in term of horsepower improvement. Rough surface can give turbulent flow thus increase the mixture of the fuel and air in combustion chamber. Smooth surface will make those fuel evaporate as the boundary layer for smooth surface is not zero and thus the fuel will touch the surface and increase the mixture of the air and fuel because both is in the same phase and condition.

Polishing works done to the Proton and Toyota intake port are mostly using Flapwheel, referring to figure 18.The other polishing works to re-smooth some sharp edges by cylindrical, ball and roll of cloth that are made from abrasives that have different type of abrasives soft types cab be referred to figure 17 to 20.

3.2.1 Polishing tools

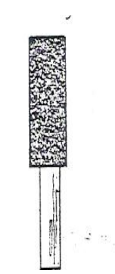


Figure 17: W179 cylindrical type abrasives

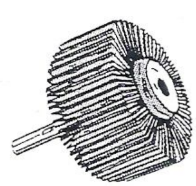


Figure 18: Flapwheel used for polishing works

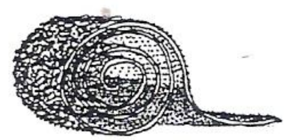


Figure 19: Roll of cloth that used for polishing

Figure 20: A25 ball type abrasives tool

3.2.2 Polishing works

Figure 21: Proton intake port after polishing modification

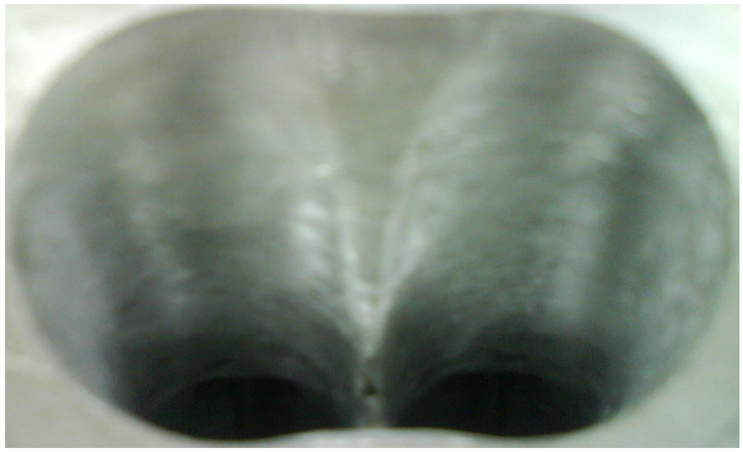


Figure 22: Toyota intake port after polishing modification

3.3 Velocity stack

Velocity stack is generally a cylindrical tube with a radiuses inlet end device which is added onto the air entry location or locations of an engines intake system, carburetor or fuel injection. It can be attached to an air box inlet or to each cylinder in an IR (individual runner).The function of it is to allow smooth and even entry of air into the intake duct with the flow streams boundary layer adhering to the pipe walls. It also modifies the dynamic tuning range of the intake tract by functioning as a small reverse megaphone which can extend the duration of pulses within the tract.

Referring to figure 23 and 24, those velocity stack used are not appropriate because it have much more different from the actual one. The surface of home made velocity stack are not smooth enough for comparison to the real one. But, for this experiment it only concern about the effect of using velocity stack to the air flow rate entered. Thus, the theory are correct and the velocity stack can increased air flow rate.